Review: Status of and Markets for Solar Thermal Power Systems

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Objectives

Provide an independent overview of the current status and commercialization issues of concentrating solar power technologies.

- Address at a "high level" three CSP technologies:
  - Trough Electric (TE)
  - Central Receiver (CR)
  - Dish/Stirling* (DS)
- Assess the current technology status and market potential in U.S. and internationally

The market segments for CSP systems can be roughly divided between grid connected and non-grid connected:

Grid Connected

Application	Typical Capacity Range	Conventional Alternatives	Applicable CSP Technologies
Commercial/Industrial Buildings (site based)	25 kW - 1,000 kW	Grid Power (at retail)	DS
Substation Support	1,000 kW - 5,000 kW	Grid Power (at substation)	DS
Central	30 MW+	Busbar Power	DS, TE, CR

Non Grid Connected (primarily developing country)

Application	Typical Capacity Range	Conventional Alternatives	Applicable SCP Technologies
Water Pumping: (irrigation)	5 kW -200 kW	◆ Diesel engines ◆ Gasoline engines ◆ Grid extension	DS
Rural Electrification	5 kW - 500 kW	◆ Diesel generators ◆ Grid extensions	DS
◆ Special Functions ◆ Refrigeration ◆ Desalination	5kW - 200 kW	◆ Diesel engines ◆ Grid extensions	DS

Market Segments: Summary:Trough Electric and Central Receiver

TE and CR technology options will, in most cases, compete with bulk power at the transmission line level of the electric utility infrastructure.

- The current strategy centers on large systems (at least 50MW for commercial-scale plants) which are too large for most distributed loads
- The land area requirements are too large for siting systems near individual loads associated with commercial or industrial activities

Operation within the utility grid will place stringent requirements on system level capital and O&M costs to be economically competitive.

CSP Technologies: Markets/Developing Countries

With the current technology strategy, both central receiver and solar trough technologies will need to be part of the central grid in most developing countries.

- One presumed advantage of solar power for use in developing countries is that it can be placed in remote locations thereby avoiding the high costs associated with serving rural loads (a major strategy for the PV industry)
- This advantage is not likely to be associated with solar trough/central receiver technologies in their current form:
  - Most rural loads in developing countries (villages, agriculture, etc.) are measured in 10’s and 100’s of kW (maybe low MW) so that the capacity of trough/central receiver systems are far too high!
- As a practical matter, therefore, TE and CR technologies in developing countries will usually be competing with grid power

Technology Status Summary: Trough Electric and Central Receiver

Experience over the last decade has significantly reduced the technical risks associated with both these technology options.

- As implemented to date, both options utilize relatively conventional steam power plant technology as the means for converting solar derived thermal energy into electricity
- Over 300 MW of solar trough technology has been operating for periods of time ranging from 10 to 15 years with reasonable (and improving) performance/reliability characteristics
- Operation of experimental central receiver systems has verified potential to operate heliostat fields with acceptable performance/reliability characteristics

The key issue is increasingly becoming verifying that stringent capital and O&M cost requirements can be achieved.

Capital Cost Issues and Uncertainties

The review documents do not make a strong case that cost targets can be achieved.

- Current costs for critical reflector fields well in excess of $\$200/m^2$
- Review documents assert reflector field cost targets (under $\$150/m^2$) can be achieved by combination of:
  - Larger production volumes, reducing per-unit costs
  - “Learning Curve” experience resulting from increased production
  - Improvement in the basic subsystem designs--for example, lighter weight structures, less expensive mirrors made from alternative materials, and lower cost tracking
- Insufficient supporting analyses were provided to assess the realism of these assertions

Verifying cost reduction potential will be critical to making a case for investments in this field.

Capital Cost Issues and Uncertainties

An independent, manufacturing cost review of a specific heliostat design provided initial support for significant cost reductions:

- Bottoms up manufacturing cost estimate indicated installed heliostat costs of about $130/m^2 (without wiring and control subsystems) at capacities consistent with 100 MW/yr
- Analyses indicated limited reduction in costs due to manufacturing scale alone (10% to 20%) i.e., without significant design changes leading to reduced material usage

O&M Cost Issues: Trough Electric and Central Receiver

Any changes in the design of the solar field to reduce capital costs must be consistent with further reductions in O&M costs (certainly no higher).

- O&M costs are divided into three main categories:
  - Cleaning of the critical reflective surfaces
  - Replacement of broken parts
  - Management of the plants and processes
- The O&M costs for the critical solar fields (parabolic troughs) have been reduced to \$13m^2 to \$18m^2 per year $\rightarrow$ impact of roughly \$0.04/kWh on power costs
- O&M cost analyses indicates the potential to reduce solar field O&M by a factor of 2, i.e., \$0.02/kWh

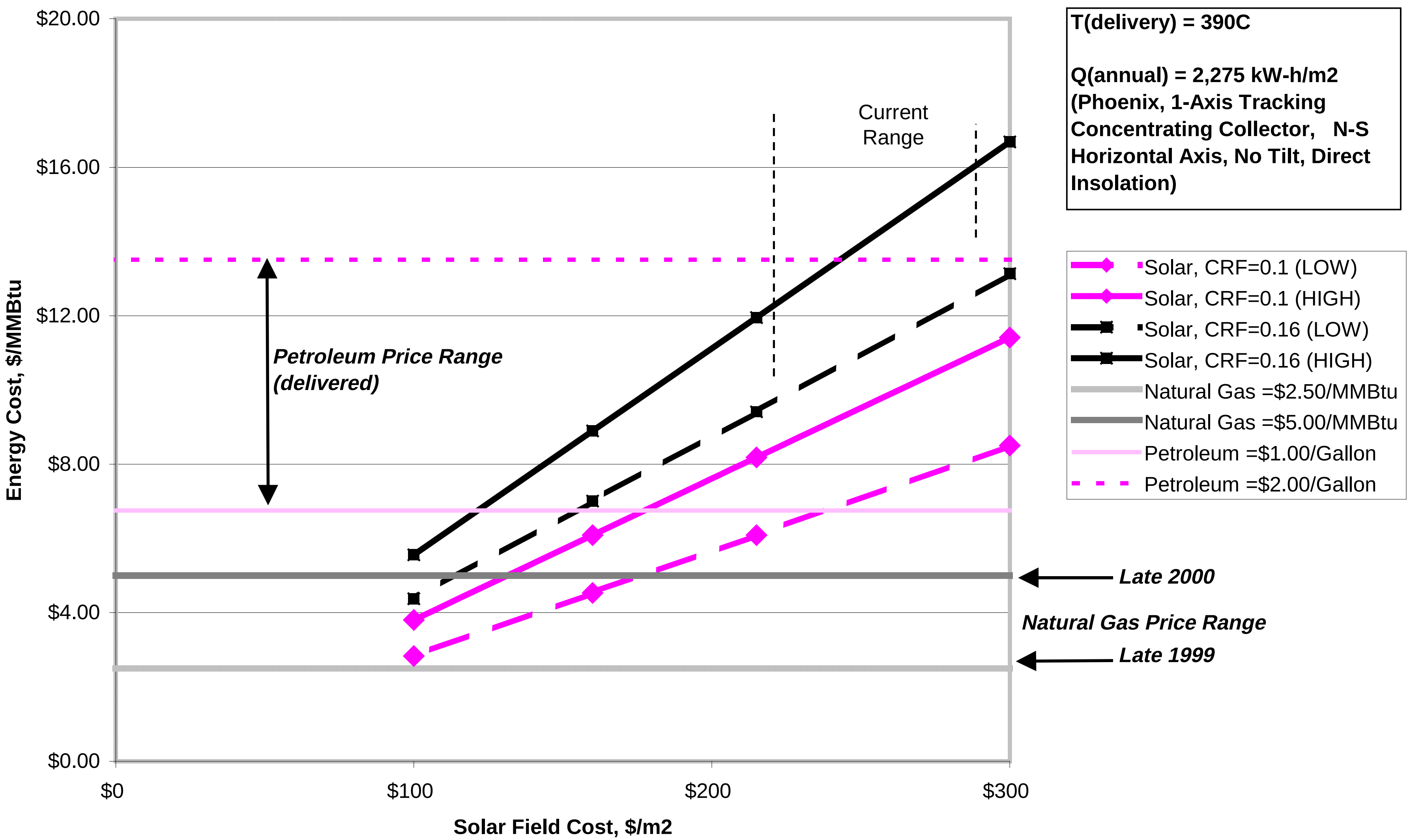
Achieving the reduced O&M costs will be critical to overall economic viability, i.e., \$0.02/kWh is at the high end of acceptability.

Economic Performance: Trough Electric and Central Receiver

Solar thermal concentrator system will most often be competing with gas as a source of power plant heat.

- Both TE and CR technologies are most often considered within a “co-firing” architecture, i.e., both gas and solar heat used to drive a steam power plant
- Estimates were made of the cost of thermal energy delivered by the solar field/receiver systems (which is independent of solar contribution details)
- The cost of thermal energy ($/MBTU) was compared to the cost of natural gas which is being displaced

Solar field costs of $150/m² would lead to delivered heat costs in the range of $5/MBTU to $8/MBTU (solar tough example)



The range reflects varying assumptions on financing structure and O&M costs.

Solar Dish Systems -- Summary

Market Characteristics

- Inherently modular technology (roughly 10-25 kW/unit) has characteristic that it could be implemented in lower field capacities (250 kW +) which allows access to a wide range of markets (note: single dish applications, however, are unlikely due to lack of installation and O&M economies of scale)
- This characteristic allows access to some non-grid connected markets allowing for cost premiums

Technical Risk

- There remains significant technical risk associated with the Stirling engine subsystem of the baseline dish/Stirling systems (limited life and O&M experience)
- The dish concentrators have inherent, (estimated at 15 - 30%) higher cost structures than troughs/heliostats

Solar Dish Systems -- Summary

Economics

- The economics (cost of power) for solar dish/Stirling are in same range as other CSP options (assuming the life/reliability of Stirling engines are verified)

Business Risk

- The modular construction of dish/engine systems allows for incremental installation and field testing of the technology with controlled financial exposure (a significant practical advantage)

Photovoltaics Transitions

- The successful development of high concentration photovoltaics to replace the Stirling engine could greatly improve system economic potential

Conclusions: Top Level

- Applications of CSP technologies in the U.S. will most often be competing with natural gas fired systems (in co-firing architectures).
- The cost of gas will need to be in excess of $5/MBTU (more likely $8/MBTU), for solar fields to be competitive with gas in delivering thermal energy to power plants.
- The price of natural gas has fluctuated significantly ($2.50/MBTU to over $8/MBTU) over the last two years.
- Highly variable (and difficult to predict) natural gas prices are a major barrier to making investments in CSP technology.
- Analysis performed in this study did not include any consideration of premium pricing options for solar systems (such as, portfolio standards or other offsets). These, of course, would hasten market entry.